

AECD - 2168

UNITED STATES ATOMIC ENERGY COMMISSION

HIGH ENERGY NEUTRON DETECTOR

by

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Date of Manuscript: April 27, 1948
Date Declassified: July 19, 1948

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Technical Information Branch, Oak Ridge, Tennessee
AEC, Oak Ridge, Tenn., 4-8-49--850-A2124

Printed in U.S.A.
~~PRICE 5 CENTS~~

DTIC QUALITY INSPECTED 3

19961016 415

215-412

APR 21 1949

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ABSTRACT

It is the purpose of this paper to describe a neutron detector suitable for monitoring a flux of neutrons whose energy is greater than about 50 Mev. Detection of the neutrons is accomplished by their ability to induce fission in heavy elements. Kelly and Wiegand* studied the neutron fission of Bi, Pb, Tl, Hg, Au, and Pt at various neutron energies and the presently described counter is an application of this work.

* * * * *

For the detectors currently in use at the Radiation Laboratory bismuth was chosen as the element which undergoes fission because it has a larger fission cross section than the elements Pb through Pt. The limited range of the fission fragments introduces the usual problem of getting a sufficient amount of the fissionable material into a position such as to enable it to project fragments into the sensitive region of the chamber. The best solution to this problem appeared to be to use a multiplicity of plates connected in the manner of a fixed capacitance, air dielectric radio condenser. A schematic drawing of the chamber is shown in Figure 1. It is self explanatory to a large extent. The original models used 28 plates of which 14 were coated on both sides with Bi. The coated plates were connected to a source of collection voltage (-800 volts). Only the high voltage electrode plates carried Bi in order that the displacement of negative ions (electrons) would be maximum and thus give larger pulses. In order to prevent leakage of charge across the surface of the polystyrene discs through which the supporting rods pass, guard rings were made by applying Aquadag to the discs in such a way as to make a grounded barrier between the supporting rods. The plates were made of aluminum 1/32 inch thick onto which was evaporated about 1 mg cm⁻² of bismuth. The area of each plate was 18 cm² and the spacing was 7/16 inch (1.1 cm). The maximum number of plates will be determined by the amount of capacitance that can be tolerated across the input of the first amplifier tube. Since the ionization produced by fission fragments is high compared with most ionizing particles the capacitance can be proportionately larger. In the chamber illustrated by Figure 1 the capacitance between collector plates and ground (with a one microfarad condenser connected between coated plates and ground) was approximately 100 $\mu\mu\text{f}$ about half of which was due to capacitance between the plates and the side walls of the chamber.

*Kelly and Wiegand, Phys. Rev. 73:1134 (1948).

That the maximum allowable capacitance was not reached in the present model chambers was indicated by the following experiment: to test the operation of the chamber before placing it in the neutron beam a small amount of Po was placed where its alpha particles were projected into the sensitive region between the plates. Upon increasing the gain of the oscilloscope, alpha particle pulses were observed which were 4 or 5 times the height of the amplifier noise background. This test indicated that the input capacitance could be increased considerably. However, if the pulses from a weak source of alpha particles can be made visible on an oscillograph screen the experimenter can readily determine whether or not the counter is in operating condition. The alpha particle pulses do not cause background counts when the detector is adjusted for fission counting because the ionization produced by the alpha particles is small compared to that from fission fragments. Some efficiency was sacrificed by not making the bismuth layers thicker. This was done in order to secure a counting rate versus bias curve for constant neutron flux which was not too steep (Figure 2). Then with proper setting of the operating bias small changes in the characteristics of the chamber, amplifier, and discriminator circuits would not seriously affect the counting rate. The ionization chamber utilizes electron collection which gives a rapid time of rise (about 0.5 microseconds) of the fission pulses so that severe differentiation can be employed in the amplifier circuits. The short decay time (about 5 microseconds) allows the amplifier to discriminate between fluctuating background ionization and the bursts of ionization from fission fragments. The fast rising pulses and the short decay time means that the amplifier is insensitive to frequencies in the audio range and therefore will not respond to microphonics and ordinary mechanical vibration. Tests with a square wave pulse generator indicate that the amplifier has a time of rise of 0.2 microseconds.

The chambers are filled to a pressure of one atmosphere with 96 per cent argon plus 4 per cent carbon dioxide. It is important that the gases be pure. Good results have been obtained using Linde argon which is prepared for use in the arc welding of aluminum. Carbon dioxide supplied for medicinal purposes has been found satisfactory as the moderating gas to increase electron mobility.

Figure 3 is a graph of counting rate versus collection voltage with constant bias and with the counter in a constant high energy neutron flux.

The efficiency of the counter was obtained by determining its counting rate in a measured neutron flux. The efficiency measurement was made with the bias of the counter set at the usual operating point on the number versus bias curve. The result was that the probability of a neutron making a fission in passing through the chamber was about 10^{-6} . This value of the efficiency could quite conveniently be doubled by increasing the number of layers of bismuth.

In a separate experiment by Kelly and Wiegand the fission cross section of bismuth was determined by counting the fissions from a thin layer of bismuth exposed to a measured neutron beam. The cross section was found to be $0.05 \times 10^{-24} \text{ cm}^2$ within about a factor of two in a beam of neutrons of average energy 84 Mev. If this value of the cross section and the known amount of bismuth which a neutron must traverse in passing through the chamber are used to calculate the efficiency of the counter a result of about three times higher than the measured efficiency is obtained. The reason for this apparent discrepancy in the thickness of the layers means that of the one mg cm^{-2} of bismuth deposited on each plate only 0.3 mg cm^{-2} is effective in projecting fission fragments into the sensitive region of the chamber.

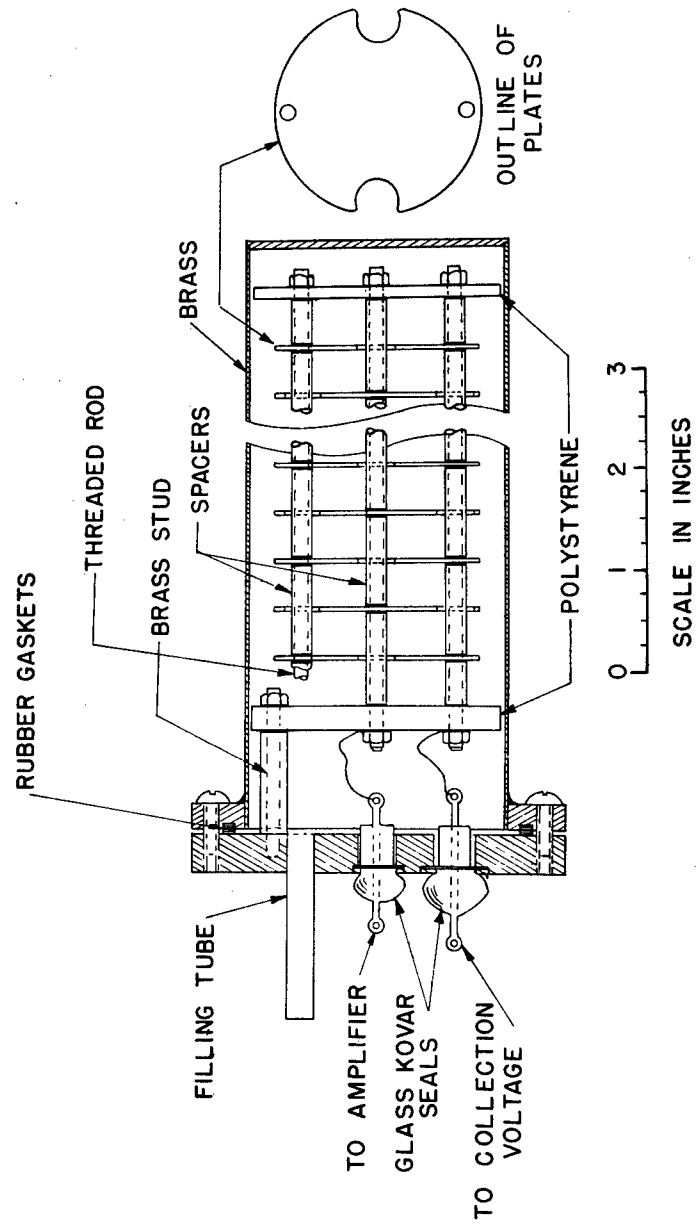


Figure 1. Schematic drawing of the high energy neutron detector. The overall length of the chamber was 16 1/2 inches.

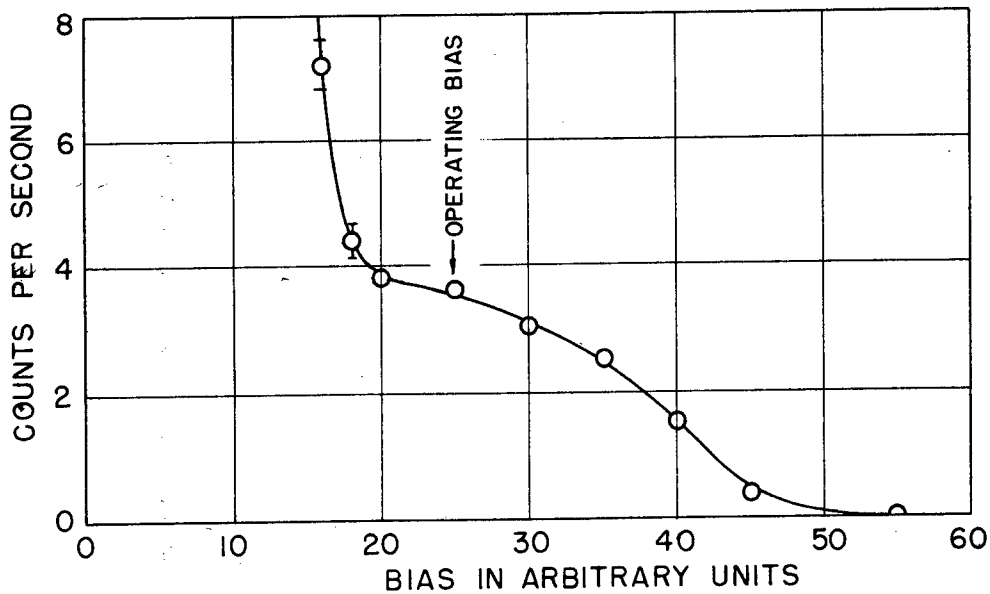


Figure 2. Counting rate versus discriminator bias with constant collection voltage and constant neutron flux.

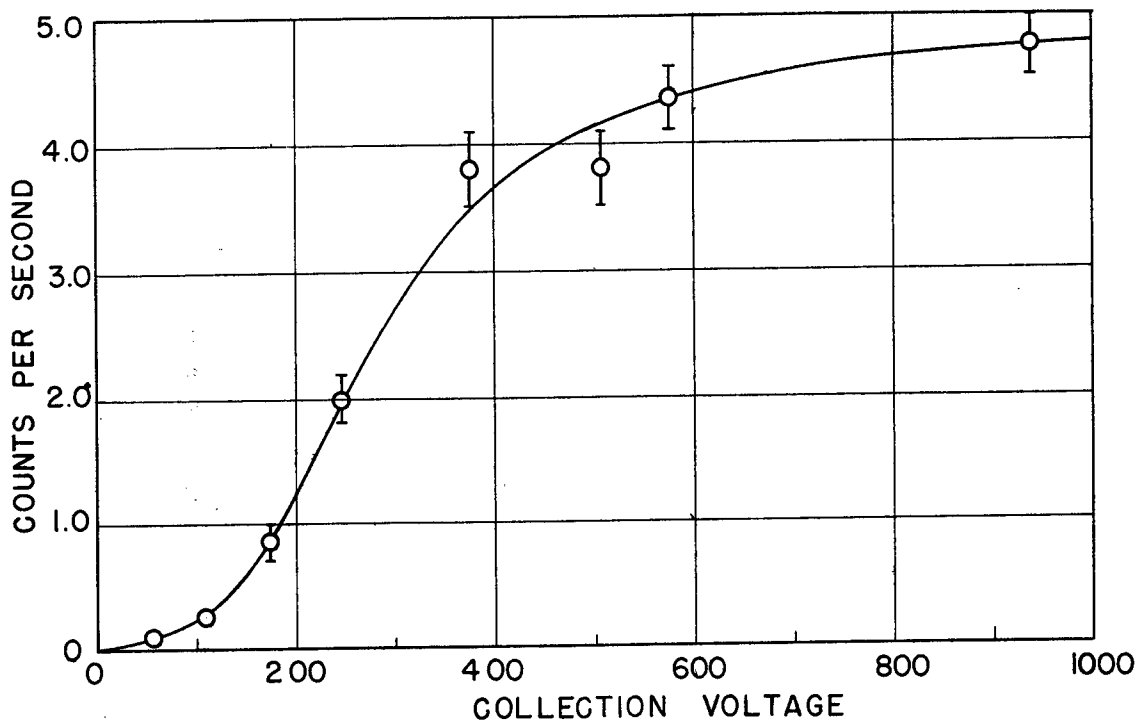


Figure 3. Counting rate versus collection voltage with constant bias and constant neutron flux.